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Should and could humans go to Mars? Yes, but not now and not in the near future

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ABSTRACT

This paper discusses rationale for human mission to Mars. Human interplanetary mission is still beyond current technological and medical capabilities. But it is also beyond social, political, financial and mental scope of humanity. This paper suggests that it is hard to find any strong rationale for human mission to Mars, which could counterbalance unovoidable risks, threats and costs.

1. Introduction

The purpose of this paper is to report and then discuss a broad spectrum of challenges relating to the idea that it is possible and also desirable to establish a permanent base for humans on Mars. Plans for crewed mission to Mars have been announced by Russian and Chinese space agencies, by the U.S. government's NASA, and by private companies including Space X. In the case of NASA, a recent space policy directive announced plans to launch first crewed missions to the Moon and then on to Mars (NASA, 2017).

In this paper I address this issue from two different perspectives. First, I ask if it's possible to come up with a rationale for such a mission that outweighs the counterarguments. I consider a wide range of proposals that have been put forward to support such a mission. Second, assuming that a rationale for undertaking such a mission does in fact exist, then it's also necessary to ask if humanity is able to prepare mentally, politically and socially to carry out this kind of long-term, multi-generational project involving sustained international support in favor of deep-space exploration. I have in mind mostly a long-term mission including the idea of establishing a permanent base on Mars. "Long-term" refers to the permanent human base even if particular crews will change in a rotational way. I will address a broad spectrum of challenges and possible threats that, considering the current level of human technological, economic, and political progress, may reduce the success of long-term human mission to Mars. It is possible that accumulation of risks and challenges combined with lack or low cost-effectiveness of this project will cause rejection of this idea (Weinberg, 2018).

2. No rationale based on cost/benefit analysis

The purpose of this essay is not a detailed analysis of all the possible pros and cons of a human spaceflight mission to Mars. This is a broad area of study that requires cooperative effort of scientists, philosophers, and public opinion experts as well. One rationale proposed for such a mission is that human spaceflight mission stimulates development in science and technology and produces new knowledge. Knowledge and progress produce useful by-products that can be applied to various fields of human life. The core of the cost-benefit analysis is the costliness of space project and the associated risk and unpredictability. Cost-benefit analysis (Baum, 2009; Ehlmann et al., 2005) includes both material and non-material values. Non-material values include human life and risk of death,

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progress in knowledge, or space refuge in case of Earth catastrophes (Baum, 2009, pp. 76–77). For instance, one of the biggest non-material benefits and sufficient rationale for human space mission is care for survival and protection of human species (Baum, 2009, p. 79).

Gonzalo Munévar (2016) shows that some critics treat the idea of human space settlement as an utopia due to its technologically challenging nature. It is hard to avoid associations with science-fiction stories when the concept of Mars base is discussed. Munévar (1986) enumerates two kinds of objections against the idea of the space settlement. Social objections are focused on the fact that space exploration leads to transfer resources and activities from necessary and real earthly problems to, in some sense fantastical and illusory, ideas. Ideological objections include objections against the risk of devastation of environment (Munévar, 1986, p. 3).

2.1. Social objections

Social objections are the cornerstone of skeptical approach to human Mars mission, mostly when compared with many unresolved social and environmental problems on Earth. The social objection argument is one of the main obstacles to those kinds of expensive activities (including not only space industry) that are perceived as extravagant and/or useless. This argument is both right and wrong. It may be right when public institutions invest money in projects that are risky, unpredictable, hard to complete, or focused on socially useless purposes. One of examples are sport champions, mostly when organized in poorer countries. This argument may sound populistically and its moral evaluation depends on particular system of beliefs and social philosophy, socialist or capitalistic. Social objection arguments may exploit the concept of sustainability. When we take for granted different kinds of risk for human life and for a living world in general, and the necessity of balanced development as the unique solution, we should consider political responsibility for financial investment in short- and long-term projects. Sustainable development includes, among others, mentioned responsibility in synchronous (care for equal and prosocial distribution of funds) and diachronic (responsibility of current generations for future generations of humans living on Earth) dimensions.

The social objection argument is wrong when inhibits or slows down progress in research and development in those long-term and relatively risky fields in which putative benefits are unclear, currently unavoidable, expected only in the future, or sometimes even unexpected and unpredictable. This question depends on context. One of factors is the current state of art in a given field, and technological and scientific progress. It includes also public education and opinions. As Sandberg et al. point out (2008), “remote” threats as nuclear war or biotechnology “may seem academic in a world plagued by immediate problems, such as global poverty, HIV, and climate change.” The problem lies in a tension between current and future/short-term versus long-term perspectives in risk detection and management.

Let us consider in this context the idea of human space missions. If effective, relatively fast and safe human journey to Mars is still impossible in 2018, it is really hard to assume that humanity will be able to settle Mars in next decades if we do not have appropriate space vehicle to leave Earth.[1] Public opinion who sponsors state budget has right to affect financial decisions mostly when some parts of humanity still cope with serious existential problems and survival needs. This kind of arguments against human space program, mostly against the idea of human space settlement, is recently discussed by, among others, Linda Billings (2017). When contrasted with social needs, space program looks like loss of public money (Panagiotarakou, 2016, p. 51). Billings not only presents social objection argument but she additionally interprets the idea of space settlement in terms of ideological, religious, and philosophical expansionism and exceptionalism. She is trying to show that neither a rational analysis nor an urgent need for humanity lies behind this idea but only a wrongly mixture interpreted national and religious ideas. Ernst Stuhlinger was faced with quite similar social objection arguments in 1970 when he tried to explain why humanity should invest in human space program even when humans face basic survival challenges in many places in the world. He argues, citing the example of the invention of microscope, that odds and apparently useless ideas should be supported due to future benefits (Stuhlinger, 1970). But benefits possibly offered by space exploration cannot be compared to the beneficial impact of microscope and progress in medical sciences in general. Benefits and inventions provided by space programs could be invented anyway, mostly if they were directly planned, designed, and produced for terrestrial purposes and not mediated by space program. In this scenario, space missions look like redundant efforts that introduce long, difficult, and indirect ways to invent products and solutions useful on Earth. Reasonable alternative is a transfer of money from space program to research and development in building environmentally useful, tested and available solutions on Earth.

The social objection argument is a very strong objection to the space program. Mostly for social reasons, rationale for human Mars mission should include pragmatic benefits. Only private investors can make this effort because they are not obliged to follow philosophy of social responsibility and sustainability as dispatchers of public funds are. The obvious challenge for private investors is their ability to take costs of risky undertaking based on long-term return of invested money.

Critics of social objection argument argue that this objection fails when is based on naïve or anecdotic idea of the budgeting process (social objection is based on social responsibility for public funds). One of them is Stuhlinger (1970) who explains that “saved” money cannot be simply transferred from one field to another. The question is not how to proceed budgets in technical terms but whether it is worth to invest public money in human space programs when the benefits are unclear. Using mentioned by Sandberg

[1] According to Pelle et al. (2018), estimated duration of journey from Earth to Mars and return journey will be between 142 and 213 days. Another question is expected minimal duration time of mission on Mars estimated between 587 and 723. In total, mission lasting more than 2 years will cause big challenge not only for health and psyche of astronauts, but simply for their physical endurance. Even if technological progress makes possible journey to Mars and back to Earth and safe Mars habitat on Earth, we should consider – also for ethical reasons – if we can send human astronauts for almost 3 years space mission.

et al. the difference in perspectives between current and remote risks, the idea of long-term human Mars mission is not only a "remote" risk (obviously, Mars mission is not treated here as a risk but as a tool designed to cope with risks). Many terrestrial risks are remote as well. The risks of overpopulation, environmental pollution or limited resources are remote at least in the extent which would cause a serious danger for humanity. Despite this fact, many governments decided to cope with these risks because these threats are reliable and unavoidable even if they will be experienced by future generations. Mars mission does not offer any serious, reasonable, and convincing arguments that would show its usefulness, necessity, and reliability, as this is the case of terrestrial remote risks. Important branch within social objection arguments is more or less intensive and inclusive connection (or, at least, usefulness) of space industry with military purposes.

2.2. No rationale based on militarization of space industry and space exploration

Space programs as, for instance, Apollo program in the past, often have political purposes. It is hard to not see obvious military context and military application of the current "space arm race" between the US, China, and Russia. Space agencies are at least partially militarized. An attempt to build "space force" announced in June 2018 by Donald Trump illustrates the case. In the world in which energy, information, and finance are based on computer systems, internet and satellite connection, dominance or at least strong position in space means dominance over the world or, at least, the power to protect own country and own interests. Space exploration sponsored by government is not oriented toward the welfare of mankind. And even if this were the case, possible solutions that could be applied in Earth are inhibited, slowed down, or just downplayed by political institutions.

While space exploration could offer benefits for science and possibly for well-being of the mankind, the most likely purpose might be militarization of the space industry. Columba Peoples (2010) shows how spacefaring countries may use space exploration to develop their military program. This is also an obstacle to the long-term human mission to Mars. Space industry at a low Earth orbit is profitable and reasonable for military purposes but military application of Mars base, mostly due to the large distance from Earth and the limited technological capacities of Mars space craft and Mars habitat, seems not very useful. If we assume that military application is the most important or just very important incentive for space exploration, there is minimal incentive in regard to mission to Mars. As Wade L. Huntley et al. (2010, p. 28) points out, old patterns of international politics based on rivalry, when equipped with new advanced space technology, will likely extend terrestrial competition to space.

2.3. "The funding wall" and high costs and risk of mission to Mars

Terrestrial and space funding do not have to be perceived as mutually exclusive activities. However, even relatively small space activity (space exploration is long and incremental process including many smaller parts that are necessary steps to build progress and to achieve next, more complex and advanced achievements) is costly. Launching the first human mission to Mars requires many activities before including a couple of robotic missions like the NASA Mars Exploration Program. NASA InSight lander focuses only on geological tests and costs around one billion dollars. Today no one is able to predict that humanity will be ready to launch human deep-space mission that will be safe and will offer any benefits. Risk of failure is high but possible benefits remain unclear. Financial capacities for deep-space human program are affected by risk of "the funding wall" (Elvis, 2016). It happens when costs needed for realization of a project increase drastically to the point when they exceed available budget. Something similar may be the case of space research programs. Failure at any stage requires extra funding to restart and/or to rework. The worst scenario occurs when planners of the mission done huge work insufficient to launch the mission.

2.4. Biological evolutionary objections

Human biology is not adapted to live in space. Living in space is deleterious for human body and psyche, and it will be hard to satisfy basic human needs (Szocik, Abood, & Shelhamer, 2018; see: NASA Human Research Roadmap). Biological challenges include not only human biology but also terrestrial ecosystem and impact of non-human animal species both on ecosystem in general, and human survival in particular (Mankins, Mankins, & Walter, 2018). One of less challenging solutions is cultivation of Earth plants on Mars. This task, if realized in greenhouses, will require the balance between sunlight needed to photosynthesis on the one side, and protection against cosmic ray on the other side. Other challenges are associated with cold temperatures and dry climate of Mars (Rappaport & Corbally, 2019). One of possible scenarios assumes the need for reconstruction of a relatively complex Earth ecosystem on Mars. This task probably requires previous terraforming of Mars. According to recent estimations, Mars carbon dioxide extracted from all possible sources on Mars offers only 6.9% of total amount of gases required for Earth-like greenhouse effect (Jakosky & Edwards, 2018). This fact excludes the concept of terraforming based on exploitation of Martian gases, and impedes exploration of subsurface liquid water resources (Orosei et al., 2018). But terraforming is not only huge technological challenge. It is unpredictable, not fully controllable process which, when applied on Mars, would delay human mission on extra couple of hundred years. But even successful terraforming is not able to remove such hazards as altered gravity and space radiation (for more challenges appropriate for Mars environment, see: Szocik, Abood et al., 2018). Human technology is not able to remove microgravity during the journey to Mars and reduced gravity on Mars.[2] It is also not able to avoid psychological challenges in space.

[2] Impey (2015),Impey, 2019 considers an opportunity of artificial Earth-like gravity in space, but he shows that this project would not be effective in terms of cost-benefit ratio.

2.5. Self-sustainability objection

Permanent or semi-permanent human base in space should be self-sustainable. Mars as a new human space settlement gets full sense only when it will be autonomous. Post-catastrophe Earth will not be able to support an expensive Mars base. In situ utilization of resources in the human space base is necessary to maintain a long-term human settlement (Carpenter, Fisackerly, & Houdou, 2016, p. 52).

3. No rationale based on space expansionism[3] and benefits for science

Terrestrial expansionism is followed by space expansionism due to limited exploratory potential on Earth. Space expansionism means not only political reality but also way of thinking about human species, human place in space, or value of life. Political dimension of space expansionism is affected by space arm race, national and patriotic feelings, commercial motivation, or scientific exploration. These reasons may work together and be united by pragmatism including some kind of cost-benefit analysis (not necessary in monetary terms as this is the case of scientific exploration or arm race). The philosophical meaning of space expansionism refers to the idea of human species as a dominating species who can freely shape and choose its own activity, create its policy, and express its ideas, emotions, and attempts. Humans are not obliged to follow any rules and duties. Space expansionism is one of many ways of expressing human thoughts and desires, especially innovativeness and creativity. Consequently, space may be explored without purpose and rationale, even against the cost-benefit ratio. While Crawford's space expansionism seems to belong to this kind of space philosophy, he enumerates more conventional benefits of space exploration including progress in science, new stimuli for human thinking and self-perception, or its possible role played in survival of human species. In regard to anthropogenic threats, Crawford does not see in this any direct impact of space exploration, and he postulates instead appropriate social policy on Earth.

Crawford is an advocate of human space exploration focused on scientific progress. As he shows, humans possess unique capacity to detect objects and phenomena that are worth of interest and study (2017b, Crawford, 2017a, p. 6.19). Human missions have obvious advantages over robotic missions due to human intellectual and manual capacities which are well beyond current space robots' abilities. Crawford (2012) emphasizes limited efficacy of robotic space missions. He is right that in current state of space technology only human astronauts are able to manage some tasks. But space science is not obvious winner of competition between various purposes and tasks supported by public budget. What is the value offered by scientific exploration, mostly when compared with other scientific disciplines? For instance, disciplines connected directly with coping with anthropogenic risks should get priority. Space exploration, even if highly valuable in purely scientific terms, does not belong to this set of strategic disciplines.[4] Space science is more like the study of the ancient world – amazing, interesting, fascinating but without pragmatic value for current societies – than medical science with pragmatic application. Perhaps true answer lies somewhere between but definitely closer to the first edge. But even if humans would be able to build research base on the Moon, Mars is well beyond current technology. In any case, if main reason for human missions are human manual and cognitive abilities needed for effective collecting lunar and Martian samples, we should instead develop AI and space robotics (advanced AI may bring risk for humanity, see: Cerka, Grigiene, & Sirbikyte, 2015).

4. No rationale based on using space as a refuge

I argue, following other authors (Baum, 2009; Baum, Denkenberger, & Haqq-Misra, 2015; Jebari, 2015; Sandberg, Matheny, & Ćirković, 2008; Turchin & Green, 2017) that human space settlement is not able to reduce and/or to exclude the risk of human extinction. For this reason, it should not be perceived in terms of space refuge. In terms of both short-term and long-term perspectives of risk assessment, it would be better to protect humans on Earth.[5] I reject the supportive role which could be played by human space settlement after a catastrophe on Earth, i.e., a recovery coordination mission. Due to so-called the paradox of technological progress discussed in the last section, further putative progress in space technology will be counterbalanced by increasing anthropogenic risks including, among others, overpopulation and limited resources (these anthropogenic threats are unavoidable in near future, in contrast to other risks that are only more or less probable but not unavoidable). Permanent lack of strong rationale for human mission to Mars – both now and in the near future – leads to paradoxical situation. Even if in some point in the future the minimum level of advancement in human deep-space technologies will be achieved, social, political, and economic contexts will gradually decrease the chances for real preparation of this mission. Another paradox, let's call it the risk dynamics paradox, is that the most probable threats in the near future are, as Bostrom and Cirkovic (2008) argue, anthropogenic threats caused by civilizational and technological progress. The paradox lies in the fact that humans are not able to run from these kinds of risks that are rooted in their way of thinking, style of life, and population dynamics, risks implied by Malthus' law. The human species can try to protect against natural disaster but not against deleterious effects of its own technological progress. In regard to possible future existential risks, I assume that their deleterious power is a little bit exaggerated, and, in any event, human space settlement is not a right way to cope with them. However, in any case, it is hard to speculate if any human space settlement must repeat the same path of human expansion as it was the case on Earth. It is unclear if human technological expansion and exploration must always lead to deleterious and self-destructive effects. In this paper, I do not discuss ethical and moral concerns which are traditionally considered when discussing the human place

[3] The term space expansionism used by, among others, Daniel Deudney and Ian Crawford (2017a).

[4] Exemptions include satellite monitoring of Earth or asteroids detection.

[5] Richard A. Posner (2004) enumerates various risks in regard to their probability and costliness, but only in the context of terrestrial solutions.

in space. They include such topics as the human right to explore space (it means both right to intervene in any extraterrestrial object, and human duty and rationale for space expansionism, mostly in the context of the idea of space refuge and possible catastrophic scenarios on Earth), or the value of human life and space objects.

4.1. The philosophy of space refuge

Philosophers and space ethicists discuss the intrinsic value of Mars, and the human right to explore and to terraform Mars (Szocik et al., in press c). I take for granted following Andreas Losch (2019) that survival of the human species is high intrinsic value which justifies space exploration and exploitation of space including terraforming and other activities expected to increase the survival of human spaces. As Baum et al. (2015) argues, it is worth doing this to protect human civilization. This rationale of advocates of human space missions is counterbalanced by the fact that real the existential risks are rather long-term. Earth still remains the unique human homeland, we are not multi-planetary species and this is still well beyond our capacities. Any effort to settle lifeless space must compete with care for Earth (Reiman, 2009, p. 83). Treating human space mission as a rescue mission sounds like a science-fiction story given the limited technological capacities and the risk of this venture. Human space settlement could work as space refuge designed to support recovery of post-catastrophe Earth population. At best, space settlement would be only a backup copy of primary Earth civilization (Baum et al., 2015).

In addition to an evacuation scenario, there is a second scenario that partially overlaps with “evacuation” scenario but explores the concept of humans as multi-planetary species. Humans should settle new place in space even if in fact future risks (epidemics, nuclear war, overpopulation, limited resources, and/or environmental pollution)[6] are lethal only for some part of population.

The idea of space refuge is a vicious circle. Investing in space refuge involves time and effort needed for coping with terrestrial risks. Public opinion may protest against space settlement program. Possible way to run away from the public opinion pressure is a top-secret status of space refuge, which is why Baum et al. (2015) discusses the importance of secrecy of this project. It seems doubtful that human base on Mars could be kept in secret. A self-sustainable base in space requires a financial effort that is incomparable with previous space activities including the ISS, human missions to the Moon, or current robotic missions. Inhabitants of self-sustainable space refuge may be not interested in taking a risk of reconstruction of post-catastrophe Earth which would be expensive, dangerous, and inhibiting for the development of the space refuge. The space refuge may be designed to become new human homeland or to be “only” additional human base with limited progress. In both cases, crew of space refuge cannot be obliged neither forced to support Earth. In post-catastrophic Earth landscape, space refuge may be better place to live. Reaction of its inhabitants is not clear.

Tony Milligan (2011), p. 193) considers space resettlements as possible solution for demographic or climate problems. Milligan argues that space settlement program should get priority as a program oriented in saving human species. Space settlement is not able to solve anthropogenic problems because space settlers will bring these problems to other planet. Even if Mars population will not reproduce (or will reproduce to low extent needed for generational succession), overpopulation on Earth will not be inhibited by building Mars settlement.

The concept of human species as endangered species is not in the center of scientific interests, as Sandberg et al. (2008). This is interesting social fact mostly in regard to social sciences and humanities. In contrast to life scientists, philosophers do not need laboratories neither extra funds to think about future threats for human species. Despite this fact, a few philosophers and humanistic scholars consider this challenge. This tendency is seen in small numbers of institutes such as The Future of Humanity Institute at University of Oxford and academic journals as *Futures* or *Bulletin of the Atomic Scientists* devoted to discuss these issues. Philosophers in general not only are not interested in future studies but they are focused mostly on history of philosophy. This tendency is stronger in Europe than in the US. Despite historians, philosophers seem to be one of the biggest groups which is focused on history. This low interest of scholars in future studies, mostly in sub-disciplines studying risks for humanity, is at least partially affected by lack or low awareness of dangers for human survival. Humans can be aware of existential risks for other animal species but refer this to themselves less often. Sandberg et al. (2008) note that, despite the fact that the probability of one extinction-level cataclysm including asteroid impact or eruption of super volcano is very low, its lethal potential for humanity justifies anti-risk prevention policy.

4.2. Anthropogenic and exogenous risks

Possible risks include nuclear winter affected by nuclear wars, asteroid impact, eruption of super volcano (the former three risks have the same effect: inhibiting the sun light, decreasing temperature, and reducing or inhibiting food production),[7] epidemics, geoengineering failure,[8] biological weapon, systemic failure (global electronic, internet, and satellite connection of the world and

[6] Existential risk may destroy intelligent life on Earth or substantially reduce its future development (Bostrom, 2002,2013); see: global catastrophes/existential catastrophes distinction (Jebari, 2015).

[7] Feeding the human population is a challenge that may be realized even during serious catastrophe on Earth (Denkenberger & Pearce, 2015). Space habitat is not only unnecessary but it will introduce new technological challenges, e.g. need for feeding people living in space.

[8] Jacob Haqq-Misra (2015) shows that geoengineering of ice caps may be important or even necessary for climatic sustainability of the planet. However, he argues that this kind of coping with greenhouse warming may lead to unexpected problems and existential risks. Geoengineering is perhaps the most dangerous and unpredictable human strategy, mostly when compared with other ways of decreasing probability of existential catastrophes. Space refuge, for instance, does not cause any risk or dangers for life on Earth.

possible global blackout), nanotechnology, and AI catastrophes (Baum et al., 2015; see also: the list of the leading existential risks in Farquhar et al., 2017). This list should be extended to include extensive fires which may be considered as a part of climate change risk. Note that two fires in Portugal in 2017 emitted total heating 68 and 142 times bigger than nuclear bomb in Hiroshima (Ribau & Hernandez, 2018). The probabilities for these threats vary in regard to their short-term or long-term perspectives, their reliability and frequency. Some are based on the unpredictability of humans, as nuclear and biological weapons attack. Other threats are unpredictable due to the current state of art, e.g. nanotechnology, AI, or bioengineering. Overpopulation and limited resources are predictable and unavoidable threats. To date, the most dangerous natural threat for survival of human species was the eruption of super volcano Toba around 75,000 years ago. There were 4000 survivors, including around 500 women in reproductive age (Rampino, 2008). Similar deleterious effects of nuclear winter and global cooling of temperature might be caused by asteroid impact. The next natural catastrophe on Earth may be fatally challenging due to human dependence on technology in food, water and energy resources.

Finally, if global technology collapses, human survival will be threatened even if relatively high number of individuals initially survive. Economic and social collapse may be greater than deleterious direct effects of natural disaster.

4.3. Demographic and biological challenges for human refuge in space

Baum et al. (2015) are concerned with capacity of crew refuge to deal with expected tasks –with their skills, psychological and physiological well-being after some catastrophe. The number of people designed to live in refuge matters genetically (founder effect and the risk of mutation in small, isolated population). The number of astronauts planned for first human missions to Mars is small, very small. Mission planners do not treat this mission in terms of long-term, space refuge-like mission, so they do not calculate the challenge of human reproduction in space. Constraints on human reproduction in space due to physiological deprivation are discussed elsewhere (Szocik, Elias Marques et al., 2018).

Estimated minimal number of individuals needed for generational sequence and mission success in a hypothetical interplanetary 6300 year journey from Earth to Proxima Centauri b is calculated as 98 persons (Marin & Beluffi, 2018). But the “sufficient founder population” will still remain as a population challenge (Baum et al., 2015). According to Chris Impey, minimum viable population is estimated at 500 individuals needed to avoid inbreeding, and 5000 to avoid extinction in long-term period (Impey, 2019).

Mission planners should also take into account genetic mutation risk. This challenge can be solved by relatively high number of crew or by migrations and interactions between inhabitants of refuge and Earth. Mission planners may design the space mission to Mars as a rescue mission for Earth where there is a gene flow maintained between space refuge and Earth.

Sufficient biological variation may decline due to post-catastrophic deprivation of Earth population. Dependently on the kind of catastrophe, Earth survivors are supposed to be modified in more or less extent due to nuclear explosion or other threats that affect human physiology. Social engineering and rigorous sexual policy should be introduced to separate crew refuge from Earth population.

Mission planners may design another variant in which space base includes human reproduction. In this case (this is the case discussed by Impey but not by Baum et al.), minimum viable population is more important than in the case of reconstruction of human population on post-catastrophe Earth. In both scenarios, another important factor is at work.

Because discussed scenarios require advanced technology for space refuge and effective interplanetary transport, we may expect application of substantial human enhancement practiced for interplanetary journeys (Zehr, 2018). The idea of human enhancement in Mars missions may be used not only to cope with space environmental challenges including mostly altered gravity or cosmic ray but also to improve physiological and psychological capacities of deep-space astronauts and, consequently, their performance and effectiveness of mission (Szocik, Campa, Rappaport, & Corbally, in press a; Szocik, Wójtowicz, Rappaport, & Corbally, in press b). Consequently, it is possible that the current state of biological knowledge will not be (or will be only partially) applied to enhanced humans living in space. CRISPR-Cas9 methods of genetic editing are just applied on Earth, and rapid progress in applied genetics connected with progress in human moral thinking may open space for human enhancement in space refuge. Less probable scenario of divergent evolution of humans living in space refuge and on Earth also should be considered, with all possible results including biological (physical and biological supremacy of primary enhanced space settlers; however, living in space is deleterious for physiology including, among others, immune system), cognitive, behavioral, or ethical effects of divergent evolution within multiplanetary human species.

4.4. Humans cannot survive by space missions

The “species-survival” argument for space exploration fails when cosmic threats are considered. When the Sun gets too warm for life on Earth, neither Earth nor Mars will be safe. Mars and Earth are both exposed to Cosmic Ray Bursts emitted by neutron stars. Such emission could be responsible for mass extinction on Earth 570 mya (Dar, Laor, & Shaviv, 1998).

Asteroid impact rather does not have potential to destroy immediately the entire life on Earth but such impact initiates long-term deleterious perturbations in atmosphere (Napier, 2006; 2015) including large scale biomass-burning (Wolbach et al., 2018). Greater risk is caused by centaurs moving in the solar system from the trans-Neptunian regions. Humanity should focus its attention on more distant regions of the solar system (Ćirković & Vukotić, 2016; Napier, Asher, Bailey, & Steel, 2015).

Risk of asteroid impact is higher on Mars than on Earth. Unless humans are not able to travel beyond the solar system, the better anti-asteroid strategy is protection on Earth (Stoner, 2017, p. 340).

4.5. There is no risk on Earth sufficient to justify the expense of a space refuge

Space refuge is justified only when there is at least one kind of catastrophe on Earth which will lead to extinction of the entire human species. Baum (2015) and Baum et al. (2015) do not believe that space settlement offers advantage over terrestrial refuge. If terrestrial refuge (aquatic and/or subterranean) is able to protect against the strongest catastrophes including asteroid impact, the unique serious rationale accepted by public opinion for space human mission fails. As Turchin and Green (2017) show, aquatic refuges based on adaptation of nuclear submarines may effectively play their role. They may be surface independent, which is the basic criterion of any refuge (Baum et al., 2015). They are cheaper and easier in engineering terms when compared with Mars settlement.

A space refuge would not be able to cope with currently-occurring risks, e.g. overpopulation and climate change. Human overpopulation can be limited only on Earth by terrestrial policy and, if this can be done, no space base is necessary. If it is not possible, then no space base can solve this problem. For example, space settlement is not able to alleviate global warming, against Milligan's suggestion. The unique way to do that on Earth is to reduce methane emission and/or to cool Earth by turning sunlight into space, as Solar Radiation Management proposes (Farquhar et al., 2017). There is only indirect, not direct applicability of space exploration. For instance, space technology might be applied to cope with asteroid impact or increasing the Sun temperature (Crawford). But these exogenous catastrophes caused by cosmic events are unlikely in lifespan of current and future generations (Tegmark & Bostrom, 2005, p. 754), and for this reason they offer poor incentive for human space program.

The unique rationale for space refuge mission could be future development of the Sun which will be getting more and more warmer in next billions years. But this threat does not justify human space settlement due to its high risk and high costliness (Jebari, 2015).

Nick Beckstead speculates on possible disasters on Earth deleterious also for humans living in shelters, e.g. scenarios that include invasion of aliens, runaway AI, or ecophagy caused by nanotechnology (Beckstead, 2015).[9] Beckstead rightly adds that the big challenge is not only rate of survival immediately after catastrophe but also chances for survival in long-term scale including collapse in food production and supply chain, and associated social and political collapse. It is hard to imagine catastrophe which kills the entire Earth population excluding people living in refuge. In this case, rationale for refuge fails.

5. Futuristic, science-fiction like scenarios as possible rationale for human space missions

Despite this critique, unquestionable advantage of any extraterrestrial object is the fact that it offers space beyond Earth in case of catastrophe on Earth. Robert Shapiro (2009) has in mind this advantage when he discusses the concept of the lunar backup copy. He rightly notes that technological heritage of human civilization should be stored in safe way because human well-being is based on advanced technology. Shapiro's solution sounds more as romantic manifesto than technologically feasible strategy. He considers the concept of the lunar base containing all or at least the most important data collected by human species. Lunar storage may be used to recover human civilization after Earth catastrophe. Shapiro enumerates mostly two benefits of lunar localization. One of them is psychologically beneficial awareness that backup copy of human achievements is stored beyond Earth. The second advantage lies in cold temperature of the Moon necessary for cooling of computer storage of data (Shapiro, 2009). This concept of space data base – Shapiro does not discuss human space refuge but he only mentions such opportunity – could be justified only if there is at least one kind of catastrophe which excludes Earth as a safe place. It seems that there are no such kinds of threats not only to safety of data storage system but even to safety of human refuge. If safe human refuge can be built on Earth, the more likely can be built safe data storage which does not need life support system. For this reason, I call Shapiro's concept a romantic attitude. He emphasizes that human space settlement missions failed historically (mostly Apollo program), and they must fail due to no rationale. Despite this reasonable observation, he suggests instead to send backup copy of human data to the Moon without special care for permanent maintenance, risk of failure, or difficulty in getting it back to Earth…

This idea has been recently extended to storing human DNA on the Moon if non-human civilization in the future would decide to reconstruct extinct human species following stored genetic instruction (Turchin & Denkenberger, 2018). Turchin and Denkenberger (2018), in contrast to Shapiro, consider a capsule of knowledge about human species including self-presenting manifesto which – when read by representatives of non-human civilization in next 100 million years from now – could inspire "aliens" to rebuild human species. I do not discuss here the doubtful value of resurrection of human species many million years after his extinction. But it is worth to discuss ethical context of this idea if some agencies, private or public, would decide to realize such project. Human beings after reconstruction by currently unknown civilization may be maltreated and exploited. Such civilization can apply genetic engineering and may reconstruct human species in any way. The question remains what would be purpose and benefit for such civilization to reconstruct humans, and why it could be valuable for humans after their extinction.

Turchin and Denkenberger take for granted reasonability of METI program which is core assumption for their idea of storing human DNA and basic information about human species. They propose to translate human language in universal language theoretically understandable for non-human civilization, based, among others, on pictures and movies (Turchin & Denkenberger, 2018).

[9] The status of epidemics and/or pandemics as existential threat is doubtful. Beckstead (2015), citing Doherty (2013) argues that even in the past when human progress in medical knowledge was weak – we can add poor hygienic standards – smaller human population did not extinct despite epidemics and pandemics. This historical track may suggest to not exaggerate putative lethal role played by future pandemics. The same – as Beckstead notes – may be the case of global food crisis which does not have to lead to human extinction.

Their proposal sounds naïvely in the light of arguments discussed by Jebari and Olsson-Yaouzis (2018). Their work may be read as a critique of METI program based on opportunity of mutual reading, decoding, and understanding languages between various civilizations. Jebari and Olsson-Yaouzis (2018) deconstruct this assumption and show that no communication is possible without interaction and context. They add that the communication event assumed in METI project (no context and no interaction) could lead to distrust and conflict between both civilizations. Because this topic is beyond the scope of my paper and it introduces the very long-term perspective which sounds more science-fiction than discussed here the challenge of human settlement on Mars, I do not discuss it in depth. In any case, this issue is indirectly connected with the question of human place in space. It considers possible rationale for space mission oriented on symbolical and cultural survival of human species, with hidden hope for his future resurrection after extinction.

As Jebari (2015) argues, human space settlement is too risky, unpredictable, and costly to become refuge. Space settlement is not feasible in political, economic, and technological terms. These three reasons are connected. Possible catastrophes on Earth have small chances to destroy the entire population including inhabitants of refuge. Last but not least. If some agencies decide to build space refuge, it is hard to believe that public opinion accept such scenario when pressure for coping with anthropogenic existential risks on Earth will be getting increased.

6. Public opinion

Public opinion is, at least in the near future, the main sponsor of space research and space exploration. Bertrand, Pirtle, and Tomblin, (2017) show that the public is interested in human mission to Mars. The most preferred space mission is a crew in orbit and a robot mission on Mars surface. In other words, public criteria is low risk and low cost. The German space agency follows public opinion and social interest because is focused on duty for society and oriented to social purposes as “climate change, mobility, communication and security” (Zypries, 2017). Politicians are prone to reduce space budgets or to not invest in long-term human settlement missions due to public opinion. Consequently, progress in space technology is still retarded. State of art in space transport means did not change qualitatively since the Space Race between the US and the Soviet Union. Impact of public opinion may differ in various countries. Max Grimard (2012), p. 6) shows how important is space program for public opinion in the US. Public sympathy for American presence in space is counterbalanced by the unpredictability of politician authorities, the tensions between presidents and the Congress (Grimard, 2012, p. 12), and the important role played by competition with Russia and China (Grimard, 2012, p. 6). Grimard adds that Russia is similar case but it is currently entire focused on stability of space programs, including renovation of old infrastructure than on new space exploration programs. According to Grimard (2012), p. 13), this fact excludes Russia from being the leader of international collaboration in space policy despite its historical advantages. China, according to Grimard, repeats space policies of the US and Soviet Union. By contrast, in Japan and Europe, prestige does not play role. Japan and Europe are focused on scientific and technological contexts. Space program is not a part of national policy. Due to its costs, politicians may decide to not risk negative approach of public opinion. But public opinion does not threaten private investors which can consider space as object of their investment.

7. Commercial exploration of space is not a workable alternative

Risk of funding the wall might be avoided by commercial exploration of space (Crawford, 2016). According to Crawford, some space projects such as next generation of large telescopes or crewed mission to Mars are non-profitable. While they are a governmental duty, they could be funded partially by profits from commercial exploration of space (for instance, space mining). Hope for private exploration sounds reasonable but is counterbalanced by commercial focus on profits. Because mission to Mars has only scientific profits, only public sponsors will be invested in this project. James S. J. Schwartz (2014) adds that two of the possible reasons for human space mission, such as improving human welfare and progress in scientific exploration, are well beyond interests of private companies. Newman and Williamson (2018) quite similarly expect that private space exploration will be focused on financial profits more than on environmental sustainability. Private investors are not obliged to act altruistically and to sacrifice their business for uncertain idea. W. Henry Lambright (2017) adds that private companies at least at first stages of Mars space program will not be able to fund it. For this reason, Mars space program requires multi-generational effort and political stabilization.

The challenge of safety works against private investors in space program. Public space agencies have achieved high standards of safety. They behave in careful and conservative ways. Commercial, private projects do not have the same advanced technology, the large number of scientists and support staff, and the generous budgets. Catastrophe would likely break a private space program. The lack of experience of private companies in space exploration is partially responsible for higher risk of technological failures even in relatively easy tasks as crash of Momo-2 rocket launched by Japanese start-up on 30 June 2018 several seconds after launch.

This does not mean that private investors are not able to explore space, but they are able to do that only when they receive profits. In scenario of commercial exploration of space, we should wait for some point in the future when a human space base appears as by-product of commercial activity. A human base on Mars might be a by-product of hotels on LEO or space mining. Some investors who want to build space hotels may try to settle space regions beyond LEO and build hotels on the Moon and/or Mars. From touristic point of view, staying in the Moon or Mars hotel may be more attractive than on LEO. Investors working in asteroid mining may extend their business to the Moon and/or Mars. Both enterprises even if focused on purely commercial purposes, will not be easy (perhaps impossible) to achieve by private companies alone. Elvis (2012), p. 549) argues that asteroid mining will be challenging due to, among others, difficulties in detection of appropriate asteroids. He shows that among about 1200 analyzed meteorites only 13 of them contain high level of platinum profitable for their exploitation. Elvis suggests that NASA should reorient its strategy from focus

on exploration to support for commercial utilization of space. Exploration will appear as a consequence of commercial profitable activity (Elvis, 2012, p. 549). Estimated profits of asteroid mining[10] are counterbalanced by high costs of exploitation and possible decreasing of price of currently rare resources (Genta, 2014).[11]

Asteroid mining is also discussed in the context of obtaining water for purpose of space economy. Such undertaking seems to be more cost-effective than transport water from Earth's surface. This optimistic scenario is hard to realize due to high costs of "first" stages, and still unpredictable and risky nature of such undertaking.

8. Human versus uncrewed space missions

The best rationale for space missions centers on uncrewed missions. Philip T. Metzger (2016) points out that economically feasible space exploration should be based on autonomous or quasi-autonomous robots. Uncrewed missions increase progress because scientists do not have to care about human safety in space. They design particular missions focused on the study of various space objects. But some tasks still may be conducted only by humans. These issues are addressed in polemics between RobertJ. Rovetto and Steven Weinberg published in *Space Policy*.

Rovetto (2013) is an advocate of human space missions. He enumerates benefits that could be provided by any large human effort as CERN laboratory or big telescopes (Weinberg, 2013, p. 229). The unique direct benefit for space exploration is quite similar to this one reported by Crawford: advantage of human astronauts over robots in managing some tasks in space. But Weinberg criticizes all the reasons enumerated by Rovetto. Weinberg's critique involves especially important counterargument. Weinberg rejects argumentation based on expectancy on spinoffs from human space programs. Because human space program improves safety of astronauts, it is not able to produce anything useful for human population living on Earth without life support system. Weinberg (2013), p. 230) suggests that in contrast to human space programs, uncrewed missions may produce more useful spinoffs in robotics and computer science. Space robotics may produce added value also for terrestrial implementation (Zypries, 2017). Instead of using human astronauts to collect cosmic samples, we should improve AI and robotics both for space and earthly applications.

Rovetto (2016), p. 70) replies that critics of human space program should not emphasize short-term threats and financial costs. He is trying to defend human space program by seeing it as a long-term project. But this is bad reasoning because humanity is familiar with long-term projects including building roads, railroad tracks, cities, or cultural and educational projects as medieval European universities (Haqq-Misra, 2019). Humanity does not face problem with long-term intergenerational projects if they offer profits and utility.

Mark Shelhamer (2017) adds to this discussion an important remark. He argues that space is still unknown and purely explored place. Humans do not know what kind of events, objects, and phenomena they can expect in space, so it is hard to design appropriate space robots. They must be designed according to parameters which can be resistant to new, unexpected space phenomena. Robotic space missions can miss important phenomena. By contrast, human astronauts can act in unexpected ways, break rules and mission strategies, and register and explore phenomena which they perceive as interesting and important. Could developed AI replace humans in this field? That's not clear.

Gonzalo Munévar (2008), p. 17) argues that the human factor slows down progress in space science. There is a big gap in the level of risk and difficulty between launching an uncrewed lander on Mars – NASA recently launched the Mars Insight Lander on 5 May 2018 – and launching first human mission to Mars. Munévar argues that focus on human missions reduces advancement in space program. A cost-benefit analysis favors uncrewed space missions using robotics and teleoperation (Munévar, 2008).

9. Humanity is not ready to crew, deep-space program

Due to the reasons discussed above, humanity is not ready to settle Mars. One of main obstacles is responsibility requiring global cooperative effort, but even if humans are able to unite to realize human space program, many unexpected risks may appear. Jacob Haqq-Misra (2019) discusses this challenge and he shows that ethical and social virtues, not current technological and medical threats, are the biggest risk for success of the mission. He argues that advance in technology requires advance in ethical and moral standards, and human space settlement will require multi-generational effort. Haqq-Misra uses the term "deep time" to describe multi-generational projects that are not profitable for generations who have to be determined to implement a deep-time project. Deep-time projects require, according to Haqq-Misra, the mental and behavioral attitude called "deep altruism." Deep altruism works when current generations decide to sponsor and support projects that will only be completed in deep future. Deep altruism account excludes material profits for the "altruists" (Haqq-Misra, 2019). They invest the resources that are the necessary first step. Without further long-term, multi-generational continuation, those first founding resources will be lost. Haqq-Misra argues that altruism is the unique attitude that makes possible cooperative effort focusing on increasing the welfare of humanity. It requires rejection of selfish, reciprocal account oriented on short-term benefits. In this context, skepticism about private initiatives in space increases. From capitalistic point of view, no one should expect that an investor will spend resources for a project that does not provide profits in his life. Such expectation is against common sense and economic theories. Governmental support for space activity is the unique because government is not selfish in this capitalistic sense, but public funding has its own objections and challenges, discussed earlier.

[10] The website asterank.com includes a large number of asteroids with projected profits in the billions to trillions of dollars.

[11] Giancarlo Genta (2014) points out that abundance of resources extracted from asteroids definitely will decrease their value. It may change their status from rare and precious metals to technical metals.

I agree with Haqq-Misra that permanent deep-space human base requires financial altruism among governmental and private investors, but any altruistic effort will be counterbalanced by two factors. First, governments must take care of current and future earth-based challenges. The rationale for deep-space human mission and human space settlement is weak. Life on Earth is not currently threatened in a way which requires evacuation of humans to other place in space, even if that were technologically possible. Second, private investors need direct benefits not only to become richer but simply to survive and to maintain their activity. Both the most selfish and the most altruistic businessmen need money to maintain their businesses. For these reasons, Haqq-Misra (2019) idea of deep altruism is rational but unrealistic. A similar objection may be formulated to Crawford (2017a),2017b) idea of federal world government designed to unite the entire mankind in his care for species survival. Perhaps world government would be able to provide political stability and permanent resources for space research and development, as Crawford suggests, but historical experience of humanity and risk of failure caused by anthropogenic threats gives solid base for skepticism.

10. The paradox of technological progress in regard to interplanetary human missions

Perhaps history of humanity does not offer strong and many examples of global collaboration but it is full of examples of original innovations and dynamical technological progress. For this reason, it seems reasonable to think that even if current state of art in space technology makes human interplanetary missions impossible, it will enable them in the future. More challenging than effective rockets for the journey to Mars is the return journey to Earth, and also creating a safe and relatively comfortable habitat on Mars. Mission planners need new solutions to current space technology. The basic challenge is the time of such a journey that's calculated to be at least 5–6 months. An ethical problem arises here if the mission involves many months of travel in unpredictable conditions and harmful environment.

But the challenge is bigger than in previous technological gaps in human history of space exploration. NASA does not possess the technology needed to organize a safe human mission to Mars.

Another challenge is Mars gravity greater than the Moon's gravity. Landing on Mars and coming back will be more challenging than in Apollo lunar program (Weintraub, 2018, pp. 6–7).

Another issue is the large distances in space between possible destinations that are theoretically available for human capacities. The challenge is not to connect New Zealand and Qatar (less than 15,000 km). The challenge is to connect Earth and Mars (around 55,000,000 km in perihelion). Forgetting for a moment about enormous challenges waiting for astronauts after landing on Mars surface and their fight for survival, the journey to Mars is challenging because Mars gravitation is such that Mars astronauts probably will have to land autonomously, without real time ground control support as in case of analogical operations currently conducted by NASA and Roskosmos). Technological challenge for a human mission to Mars is complex, and what has been mentioned so far is only prelude to the challenges of living on Mars surface. The basic problem that distinguishes mission to Mars from missions to the Moon is that astronauts who land on Mars probably will not be able to come back Earth after a stay of only a few days. One issue is deleterious impact of long journey on their physical and psychological health, and paradoxically, Mars habitat is not the best place for recovering after such exhaustive journey. Because human mission to Mars will be a big effort – both in terms of preparation of the mission on Earth and then the long journey to Mars –we can expect that mission planners and organizers, and public opinion may expect a relatively long stay on Mars. This is obviously a bigger challenge than a one-way spacecraft trip to Mars.

The current state of the art in space technology makes a successful mission to Mars impossible both now and in the near future. There is no analog of a long-term Mars mission in any previous and current human space programs. Apollo program did not include long staying of astronauts in habitats on the Moon, and the journey to the Moon is substantially shorter than journey to Mars. The full time of Apollo 11 mission in 1969 was 8 days including journey to the Moon, staying there almost one day, and return journey to Earth. This is important in case an emergency because both during the stay on the Moon base or during flight problem. The good illustration of the latter case is Apollo 13 mission in 1970. Something like "in case of emergency" does not exist in human mission to Mars. Mars crew cannot count on real time ground mission control support due to communication delay. An evacuation mission or rescue mission will be impossible, at least in the first years of Mars space program. Even if the next rescue spacecraft could be sent from Earth – if it was feasible technologically and economically – its 6–9 months journey to Mars could be too long to offer help for Mars astronauts in need. The model of astronauts who stayed at the ISS for more than one year non-stop should not be treated as equivalent of future Mars astronauts staying on Mars. ISS is not a good analog for Mars habitat for many reasons. Astronauts who stay at ISS are able to leave the ISS in a couple of hours. There are also some basic differences caused by distance and by exposure to cosmic rays that undercut analogies between a human mission to ISS, to the Moon and a mission to Mars. For these reasons, Borowitz and Battat (2016) argue that cis-lunar habitat space missions should be the next target for collaborative effort of spacefaring states in their route to Mars.

These basic challenges appropriate for human mission to Mars shows how fragile and risky is human factor in a mission to Mars (Szocik, 2019). The unique receipt for successful space exploration is to develop and to invest in robotic, without a human crews space missions.

The risk of catastrophic failure also cannot be excluded. In the briefly mentioned human progress in building and testing aircrafts, there is obvious correlation between failures and advance in flight technology. It seems that this progress would not be possible without failures. Failures are impossible to avoid because some challenges and risk factors were impossible to predict and to test before they happened. Some limitations appear only during flights. Aircraft accidents often led to changes in technological solutions, training procedures, and flight control rules. Something similar may be expected in regard to human mission to Mars. Some failures (Apollo 13) or even lethal catastrophes (NASA space shuttles in 1986 and 2003) show that risk of failure is relatively high. During a mission to Mars, this risk increases due to the long journey and the delay in communication between astronauts and mission control

on the ground. NASA fatal accidents in 1986 and 2003 attracted media interest and led to the cancellation of the human spaceflight program, but here cultural differences may be important. Chinese Xichang space disaster in 1996 did not cancel Chinese space programs (Szocik, Wójtowicz et al., in press b). The question of safety and the risk of failure is especially challenging for private initiatives when because accidents may result in canceling the entire program (Genta, 2014).

Let us assume that, due to unknown reasons, there will be mission planners and mission organizers who decide to sponsor as fast as possible progress in space technology. Let us assume that they will do that independently based on cost-benefit analysis or that they will treat the human mission to Mars as beneficial in any terms, not necessary in monetary one. We should not expect to get such technologies earlier than after a couple of decades. The essence of the second idea of the paradox of technological progress lies in this time issue, i.e. in the distance from now to the point in the future when appropriate technology will be achieved. No one can predict political, social and economic situation in next decades. The current social and political conditions which theoretically could enable this big technological effort, do not exist now. One anthropogenic risk, overpopulation, is unavoidable. The current human population of Earth, about 7.6 billion, is estimated to grow until around 10.0 billion for 2050. Overpopulation is associated with limited and permanently depleting resources. Climate changes may only worse these issues. It is hard to predict the next decades of Earth in political, social, and economic terms. There is always the risk of wars and conflict, and the effects on resources. In this scenario, long-term project of progress in space technology may be endangered, and its continuity may be easily interrupted, even if it is the case that technological readiness to human space Mars mission is achieved in next decades. We should expect that global situation will be worse than it is now due to overpopulation and limited resources. Therefore, the chances for social, public opinion support for such mission seem likely to decrease, not increase, with time. We cannot expect that new, currently unknown or unrealistic rationale for a long-term mission to Mars will appear in next decades. Such rationale may not appear for billions of years. The worse political, social and financial situation is, the lower chances for social and public acceptance and support for human space missions are. Only sufficiently strong rationale could rescue this project. Similar problem was reported by Shapiro (2009) who proposes, as a remedy that would justify the sense of space mission, the concept of extraterrestrial backup copy of terrestrial digital data. There are no strong rationale that could be put successively into broader social and political context of current world. Even if value of human life is the highest value, and even if making the human species a multi-planetary species would be the best way to increase its chances for survival, this task is not only unrealistic but even impossible to imagine in currently available technology.

Milligan (2011) discusses argument from duty to extend human life. Interplanetary settlement is one of ways of realization of this duty. He adds that humanity should do that by, among others, involving private companies to invest in space technology (Milligan, 2011, p. 191). I find here at least four unjustified assumptions. First, even if there is duty to extend human life, it is not an absolute postulate, is still a relative value which should take into account issues pertaining to ecosystem and sustainable development. Second, there is no reliable analysis which shows that space expansion is the best and/or at least necessary option. No one is able to anticipate and to calculate cost to benefit ratio of such unprecedented project in human history as a mass exodus to Mars (or elsewhere in space). Third, following the ethics of quality of life, we have duty to take care for some minimal level of quality, comfort, pleasure, and well-being of the mankind. Living on post-catastrophe Earth in any kind of refuge still may be a better place to live than Mars habitat. Needless to say that physical properties of Mars including reduced gravity or cosmic ray may be the source of permanent harm and deprivation (the full lists of physiological risks in space, see: Letter Report, 2016). Is living in small, confined, and relatively unsafe Mars habitat worth risking human life? Fourth, Milligan proposes that private companies will want to invest in the space industry. But the capitalistic idea of privatization has some limitations. As classic economic theories state, this idea may be applied only when cost-benefit ratio is profitable for the private investor. This common economic knowledge shows that the main difference between public and private investors lies in their different approaches to profits and responsibility. Expected benefits should justify risk and costs of investing by private investor but this is not the case of space missions (Genta, 2014). Max Grimard (2012), p. 2) takes for granted that private investors are not long-term oriented, mostly in deep-space missions where there are no direct benefits. Only a public investor permanently sponsored by taxes can conduct long-term, intergenerational project that is not oriented toward profits. Public transport and public medical care are good illustrations of systems oriented on common welfare, not profits. They are continued despite failures and risks. Another example is building of public roads. Despite possible exemptions, only governments are able to invest in building many kilometers of highway, tunnels, or bridges. In some cases, private investors and/or their consortium realize such projects but only within public-private partnership. After that, they get back invested money by charges paid for use of the roads. Space industry faces challenges. First, it is obliged to take big effort to get access to effective human space mission projects. Even the shortest scenario of human mission to Mars is a complex task including journey to Mars, habitat on Mars, infrastructure enabling launch, and return journey to Earth. Permanent concerns are human psychological and physiological health and basic human survival. Possible profits which could attract possible private investors are unclear. Currently achievable profits in space industry include Earth observation or telecommunication (Borowitz & Battat, 2016), but that is not likely enough.

Second, putative future final products as safe spacecraft and safe space habitat require long-term, perhaps intergenerational effort and investing which will not be refundable neither profitable. The problem arises when no real and possible profits are expected. Even if commercial companies would be able to invest their money in interplanetary project, why they should do that? How could they earn money by sending people to Mars? Who will pay for it? Can we expect that at least one millionaire decides to go to Mars? How much he should pay for this service to make it profitable for investors to cover costs of multi-decade efforts preceding preparation of first flight? Current commercial space projects as cargo service provided by Space X or planned in the near future space tourism including trips to low Earth orbit and space hotels, or asteroid mining are substantially different than human mission to Mars. Advocates and enthusiasts of private sector miss this difference. There is a big substantial technological gap between Elon Musk's investment to the ISS, and an entrepreneur's capacity to organize human mission to Mars.

11. Conclusions

Deep faith in power of human reason supported by experience and experiments is not enough to organize safe and effective human mission to Mars. The main obstacle to go to Mars now and in the near future is a technological barrier. Future technological advancement may be counterbalanced by increasing threats. The risk of catastrophes and threats is increasing every year. Challenges associated with overpopulation, limited resources and climate changes including extensive fires probably will inhibit any serious investing in human space program. Only an urgent, real, and serious rationale would be able to argue for need for current long-term, deep-space human interplanetary program, but there is no such urgent rationale now and probably it will not appear in the near future. Human interplanetary missions look more like an extravagant display of human creativity, complacency, and high self-esteem than like a real need of humanity and a real possibility. The multi-generational international collaboration that seems to be necessary for effective human mission to Mars is problematic for political and financial reasons.

Last but not least. I did not find in papers discussing the idea of refuge (Baum et al., 2015; Jebari, 2015; Turchin & Green, 2017) any deep analysis of the psychological challenge of living in a close, confined shelter or capsule, whether in an earthly or a space habitat. This challenge may be greater in space refuge but we may expect that many years of isolation in nuclear submarine may be psychologically deleterious as well.[12] Rappaport and Corbally (2019) in excellent and detailed way show how challenging psychologically will be every minute of life in confined Mars base. Their analysis may be referred to Earth refuge as well. This psychological harm raises ethical questions. Among them one of the most important is the basic question of the ethics of quality of life: is such kind of life worth to be alive?

Interplanetary human mission planners and organizers should focus more on human factor in a mission to Mars. They should take into account the broad set of mutually connected factors including public opinion, increasing risk of anthropogenic threats, unpredictability of global social and political situation in next decades, or progress in robotics and AI which may lead to cancellation of human space missions.

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References

Baum, S. D. (2009). Cost-benefit analysis of space exploration: Some ethical considerations. *Space Policy, 25*, 75–80.
Baum, S. D. (2015). *Confronting the threat of nuclear winter. Futures*.
Baum, S. D., Denkenberger, D. C., & Haqq-Misra, J. (2015). Isolated refuges for surviving global catastrophes. *Futures, 72*, 45–56.
Beckstead, N. (2015). How much could refuges help us recover from a global catastrophe? *Futures, 72*, 36–44.
Bertrand, P., Pirtle, Z., & Tomblin, D. (2017). Participatory technology assessment for Mars mission planning: Public values and rationales. *Space Policy*. https://doi.org/10.1016/j.spacepol.2017.08.004.
Billings, L. (2017). Should humans colonize other planets? No. *Theology and Science*. https://doi.org/10.1080/14746700.2017.1335065.
Borowitz, M., & Battat, J. (2016). Multidisciplinary evaluation of next steps for human space exploration: Technical and strategic analysis of options. *Space Policy, 35*, 33–42.
Bostrom, N. (2002). Existential risks: Analyzing human extinction scenarios and related hazards. *Journal of Evolution and Technology, 9*(1).
Bostrom, N. (2013). Existential risk prevention as global priority. *Global Policy, 4*(1), 15–31.
Bostrom, N., & Cirkovic, M. (Eds.). (2008). *Global catastrophic risks*. Oxford, New York: Oxford University Press.
Carpenter, J., Fisackerly, R., & Houdou, B. (2016). Establishing lunar resource viability. *Space Policy, 37*, 52–57.
Cerka, P., Grigiene, J., & Sirbikyte, G. (2015). Liability for damages caused by artificial intelligence. *Computer Law & Security Report*. https://doi.org/10.1016/j.clsr.2015.03.008.
Ćirković, M. M., & Vukotić, B. (2016). Long-term prospects: Mitigation of supernova and gamma-ray burst threat to intelligent beings. *Acta Astronautica, 129*, 438–446.
Crawford, I. A. (2012). Dispelling the myth of robotic efficiency: Why human space exploration will tell us more about the Solar System than will robotic exploration alone. *Astronomy & Geophysics, 53* 2.22-2.26.
Crawford, I. A. (2016). The long-term scientific benefits of a space economy. *Space Policy*. https://doi.org/10.1016/j.spacepol.2016.07.003.
Crawford, I. (2017a). Why we should build a Moon village. *Astronomy & Geophysics, 58* 6.18-6.21.
Crawford, I. (2017b). *Space, world government, and a 'Vast future' for humanity*. http://wgresearch.org/space-world-government-vast-future-humanity/.
Dar, A., Laor, A., & Shaviv, N. J. (1998). Life extinctions by cosmic ray jets. *Physical Review Letters, 80*, 5813.
Denkenberger, D. C., & Pearce, J. M. (2015). Feeding everyone: Solving the food crisis in event of global catastrophes that kill crops or obscure the sun. *Futures, 72*, 57–68.
Doherty (2013). *Pandemics: What everyone needs to know*. New York: Oxford University Press.
Ehlmann, B. L., Chowdhury, J., Marzullo, T. C., Collins, R. E., Litzenberger, J., Ibsen, S., et al. (2005). Humans to Mars: A feasibility and cost-benefit analysis. *Acta Astronautica, 56*(May-June (9–12)) 851-8.
Elvis, M. (2012). Let's mine asteroids – For science and profit. *Nature, 485*, 549.
Elvis, M. (2016). What can space resources do for astronomy and planetary science? *Space Policy*. https://doi.org/10.1016/j.spacepol.2016.08.001.
Farquhar, S., Halstead, J., Cotton-Barratt, O., Schubert, S., Belfield, H., & Snyder-Beattie, A. (2017). *Existential risk*. Diplomacy and Governance.
Genta, G. (2014). Private space exploration: A new way for starting a spacefaring society? *Acta Astronautica, 104*(2), 480–486.
Grimard, M. (2012). Will the US remain the real leader of human space exploration? A comparative assessment of space exploration policies. *Acta Astronautica, 75*, 1–14.
Haqq-Misra, J. (2015). Should we geoengineer larger ice caps? *Futures, 72*, 80–85.
Haqq-Misra, J. 2019. Can Deep Altruism Sustain Space Settlement? In Human factor in a mission to Mars, K. Szocik (ed.), Springer, In preparation. ISBN 978-3-030-02059-0.
Huntley, W. L., Bock, J. G., & Weingartner, M. (2010). Planning the unplannable: Scenarios on the future of space. *Space Policy, 26*, 25–38.

[12] If underwater habitat is a good analog for space exploration (NASA NEEMO project, see: NASA, 2018), perhaps it would be better to focus on undersea habitats and future underwater refuge.

Impey, Ch. (2015). *Beyond. Our future in space.* W. W. Norton & Company.
Impey, Ch. 2019. Mars and Beyond: The Feasibility of Living in the Solar System. In Human factor in a mission to Mars, K. Szocik (ed.), Springer, In preparation. ISBN 978-3-030-02059-0.
Jakosky, B. M., & Edwards, Ch. S. (2018). Inventory of CO2 available for terraforming Mars. *Nature Astronomy, 2*, 634–639.
Jebari, K. (2015). Existential risks: Exploring a robust risk reduction strategy. *Science and Engineering Ethics, 21*(3), 541–554.
Jebari, K., & Olsson-Yaouzis, N. (2018). A game of stars: Active SETI, radical translation and the Hobbesian trap. *Futures.* https://doi.org/10.1016/j.futures.2018.06.007.
Lambright, W. H. (2017). Relay leadership and long-term policy: The case of Mars. *Space Policy, 42*, 1–7.
Letter Report (2016). *Review of NASA's evidence reports on human health risks*Washington DC: The National Academies Press.
Losch, A. 2019. Interplanetary Sustainability. Mars as a means of a long term sustainable development of humankind in the solar system? In Human factor in a mission to Mars, K. Szocik (ed.), Springer, In preparation. ISBN 978-3-030-02059-0.
Mankins, J. C., Mankins, W. M., & Walter, H. (2018). Biological challenges of true space settlement. *Acta Astronautica, 146*, 378–386.
Marin, F., & Beluffi, C. (2018). Computing the minimal crew for a multi-generational space journey towards Proxima Centauri b. *JBIS, 71*, 431–438.
Metzger, P. T. (2016). Space development and space science together, an historic opportunity. *Space Policy*. https://doi.org/10.1016/j.spacepol.2016.08.004.
Milligan, T. (2011). Property rights and the duty to extend human life. *Space Policy, 27*, 190–193.
Munévar, G. (1986). Space colonies and the philosophy of space exploration. *AIP Conference Proceedings, 148*(2), https://doi.org/10.1063/1.36021.
Munévar, G. (2008). Humankind in outer space. *International Journal of Technology, Knowledge and Society, 4*(5), 17–25.
Munévar, G. (2016). Space colonies and their critics. In J. S. J. Schwartz, & T. Milligan (Eds.). *The ethics of space exploration* (pp. 31–45). Springer.
Napier, W. M. (2006). Evidence for cometary bombardment episodes. *Monthly Notices of the Royal Astronomical Society, 366*, 977–982.
Napier, W. M. (2015). *Giant comets and mass extinctions of life. Monthly notices of the Royal astronomical society*, *448*, NASA27–36. Mars 2020 Mission Overview. retrieved from: https://mars.nasa.gov/mars2020/mission/overview/.
Napier, B., Asher, D., Bailey, M., & Steel, D. (2015). Centaurs as a hazard to civilization. *Astronomy & Geophysics, 56*(6), https://doi.org/10.1093/astrogeo/atv198 6. 24–6.30.
NASA (2017). *New space policy directive calls for human expansion across solar system.* retrieved from:https://www.nasa.gov/press-release/new-space-policy-directive-calls-for-human-expansion-across-solar-system.
NASA (2018). *Neemo.* retrieved from:https://www.nasa.gov/mission_pages/NEEMO/index.html.
Newman, Ch. J., & Williamson, M. (2018). Space sustainability: Reframing the debate. *Space Policy*. https://doi.org/10.1016/j.spacepol.2018.03.001.
Orosei, R., Lauro, S. E., Pettinelli, E., Cicchetti, A., Coradini, M., Cosciotti, B., et al. (2018). Radar evidence of subglacial liquid water on Mars. *Science, 25*(July), https://doi.org/10.1126/science.aar7268 2018: eaar7268.
Panagiotarakou, E. (2016). Agonal conflict and space exploration. In J. S. J. Schwartz, & T. Milligan (Eds.). *The ethics of space exploration* (pp. 47–60). Springer.
Pelle, S., Gargiol, E., Berga, M., Pisacreta, J., Viola, N., Della Sega, A., et al. (2018). Earth-Mars cyclers for a sustainable human exploration of Mars. *Acta Astronautica*. https://doi.org/10.1016/j.actaastro.2018.04.034.
Peoples, C. (2010). The growing 'securitization' of outer space. *Space Policy, 26*, 205–208.
Posner, R. A. (2004). *Catastrophe: Risk and response.* Oxford University Press.
Rampino, M. R. (2008). Supervolcanism and other geophysical processes of catastrophic import. In N. Bostrom, & M. Cirkovic (Eds.). *Global catastrophic risks*. Oxford, New York: Oxford University Press.
Rappaport, M. B., and Ch. Corbally. 2019. Program planning for a mars hardship post; social, psychological, and spiritual services. In Human factor in a mission to Mars, K. Szocik (ed.), Springer, In preparation. ISBN 978-3-030-02059-0.
Reiman, S. (2009). Is space an environment? *Space Policy, 25*, 81–87.
Ribau, M. C., & Hernandez, A. G. (2018). *Incendios como bombas atómicas.* retrieved from:El Paishttps://elpais.com/elpais/2018/07/24/opinion/1532457837_710821.html.
Rovetto, R. J. (2013). The essential role of human spaceflight. *Space Policy, 29*(4), 225–228.
Rovetto, R. J. (2016). Defending spaceflight – The echoes of Apollo. *Space Policy, 38*, 68–78.
Sandberg, A., Matheny, J. G., & Ćirković, M. M. (2008). How can we reduce the risk of human extinction? *The Bulletin of the Atomic Scientists*.
Schwartz, J. S. J. (2014). Prioritizing scientific exploration: A comparison of the ethical justifications for space development and for space science. *Space Policy*. https://doi.org/10.1016/j.spacepol.2014.08.010.
Shapiro, R. (2009). A new rationale for returning to the Moon? Protecting civilization with a sanctuary. *Space Policy, 25*, 1–5.
Shelhamer, M. (2017). Why send humans into space? Science and non-science motivations for human space flight. *Space Policy, 42*, 37–40.
Stoner, I. (2017). Humans should not colonize mars. *Journal of the American Philosophical Association,* 334–353.
Stuhlinger, E. (1970). *Why explore space?* http://www.lettersofnote.com/2012/08/why-explore-space.html.
Szocik, K. (ed.). 2019. Human factor in a mission to Mars. Springer, In preparation.
Szocik, K., Abood, S., & Shelhamer, M. (2018). Psychological and biological challenges of the mars mission viewed through the construct of the evolution of fundamental human needs. *Acta Astronautica* in press.
Szocik, K., Elias Marques, R., Abood, S., Lysenko-Ryba, K., Minich, D., & Kędzior, A. (2018). Biological and social challenges of human reproduction in a long-term Mars base. *Futures, 100*, 56–62.
Szocik, K., Campa, R., Rappaport, M. B. and Ch. Corbally. *In press* a. The Special Case of Modifications to Counter Bone Loss for Manned Mars Missions.
Szocik, K., Wójtowicz, T., Rappaport, M. B., and Corbally, Ch. *In press* b. Mission to Mars: A Challenge for the Ethics of Human Biology.
Szocik, K., Impey, Ch., Elvis, M., Shelhamer, M., Haqq-Misra, J., Persson E. et al. *In press* c. Visions of a Martian Future: The Evolutionary, Ethical, Anthropological and Psychological Challenges of a Permanent Mars Settlement.
Tegmark, M., & Bostrom, N. (2005). Is a doomsday catastrophe likely? *Nature, 438*(8), 754.
Turchin, A., & Denkenberger, D. (2018). Surviving global risks through the preservation of humanity's data on the Moon. *Acta Astronautica, 146*, 161–170.
Turchin, A., & Green, B. P. (2017). Aquatic refuges for surviving a global catastrophe. *Futures, 89*, 26–37.
Weinberg, S. (2013). Response: Against manned space flight programs. *Space Policy, 29*(4), 229–230.
Weinberg, S. (2018). *Third thoughts.* Harvard University Press.
Weintraub, D. A. (2018). *Life on Mars. What to know before we go.* Princeton and Oxford: Princeton University Press.
Wolbach, W. S., Ballard, J. P., Mayewski, P. A., Parnell, A. C., Cahill, N., Adedeji, V., et al. (2018). Extraordinary biomass-burning episode and impact winter triggered by the younger Dryas Cosmic impact ~12,800 years ago. 2. lake, marine, and terrestrial sediments. *The Journal of Geology,* 126.
Zehr, P. E. (2018). *Captain America on Mars.* https://blogs.scientificamerican.com/observations/captain-america-on-mars/.
Zypries, B. (2017). Viewpoint Brigitte Zypries parliamentary state secretary federal government coordinator of german aerospace policy space, the public, and politics. *Space Policy*.